The Report committee for Garrett Spain Johnson certifies that this is the approved version of the following report:

Serious Games for Serious Purposes: Learning Through Simulation Games in Medical Education

SUPERVISING COMMITTEE:

Diane L. Schallert, Supervisor

Stephanie B. Corliss

Serious Games for Serious Purposes: Learning Through Simulation Games in Medical Education

by

Garrett Spain Johnson

Report

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfilment

of the Requirements

for the Degree(s) of:

Doctor of Medicine

and

Master of Education

The University of Texas at Austin

May 2020

Serious Games for Serious Purposes: Learning Through Simulation Games in Medical Education

by

Garrett Spain Johnson, MD, MEd

The University of Texas at Austin, 2020

SUPERVISOR: Diane Schallert

Serious games provide an exciting new technology for the field of education. Within medical education, this is especially true as serious games can provide novel learning experiences that students may otherwise not be able to have. In order to reach their full utility, games must be examined closely for how they may function in helping students learn. This report argues that achievement emotions, as presented in control-value theory, are an important aspect that needs attention during the implementation and incorporation of serious games into the curriculum of medical schools. Following such an argument, recommendations are made in support for the incorporation of serious games into the curriculum of a particularly innovative medical school. Benefits and limitations of serious games are reviewed.

Table of Contents

CHAPTER 1: INTRODUCTION

Shelter-in-place. This is what I had been doing for several weeks during the COVID-19 pandemic. Staying at home, doing my part to stop the spread. Minimize contacts, and only go out for essential functions. I can do this; no problem.

But then the conflict sets in. I'm a fourth-year medical student. I'm about to be a doctor working in the Emergency Room. I was supposed to be on a trauma surgery rotation to complete my last month in medical school, but now, I'm sheltering-in-place.

I want to talk to a patient. I want to help someone. I want to do what I came to medical school to do. Although I understand the decision to take medical students out of the hospitals, I feel a part of me is gone and I can't fill that void. I can read about diseases and conditions, I can look at the latest research articles about coronavirus, but it's all out of context and without a direct utility. Sure, I'll need to know all of this in a few months when I start my residency, but the literature and what we know will change between now and then.

I scroll through my unread email and see that I have an *Oxford Medical Simulation* requirement sent to me by my medical school. I've never heard of that. I am to download some software (2 GB, that's a big download!), set up an account, and do five virtual simulation modules on the Oxford platform. Not a bad way to kill some time. I

wait on the download, set up an account, do some expected troubleshooting to get everything up and running, and then start the first case.

The icon I click to launch this case says, “65-year-old female who is short of breath.” I think, ‘Short of breath, that could be any number of things.’ The simulation starts, and all of a sudden I’m looking at a nurse who says, “Ms. Jones is here because she is having trouble breathing. I’m really concerned about her. Can you come see her now?” A cut screen puts me at the bedside of Ms. Jones. I hear the hustle-and-bustle of people moving around outside the room. There is the familiar beeping of monitors. I must be in the emergency room of the simulation hospital. Ms. Jones looks up at me and says, “I’m having trouble breathing. I don’t know what’s wrong.” ‘Neither do I,’ I think. A number of reasons why she would be short of breath run through my head, but I realize there aren’t any vital signs displayed on the vital sign monitor which is positioned in the simulation exactly where I would expect it to be in real life. I move my mouse over the nurse, and a prompt “Place nursing orders” appears. I click, and one of the requests that can be made is to place vital sign monitors on the patient. ‘Let’s start with that.’ The virtual nurse moves to place the probes onto Ms. Jones and I scroll the mouse over Ms. Jones and it says, “Ask patient history questions,” when I do. ‘Let’s get some more information about this shortness of breath.’ When I click on this, a large number of options appear, all related to topics and questions I could ask Ms. Jones. Should I ask about smoking history? What about travel history? Fevers? The options are plenty, when I notice out of the corner of the screen a timer, ticking down and currently around 13 minutes. ‘I need to prioritize my questions or I’ll run out of time.’

I start with the broad question of "tell me more about what's going on," as I had been taught to do in medical school, and direct more specific questioning based on what Ms. Jones says. As she starts talking, I see the vital signs come up on the monitor. To my surprise, the numbers displayed are the same colors I have become accustomed to in the hospital. However, her oxygen saturation is only 88%, and I think, 'should probably do something about that.' I turn my gaze to the wall, and exactly where I would expect the oxygen connection to be, the familiar green knob and floating ball are there. I click on this, and now another decision: nasal cannula, simple facemask, or nonrebreather? 'Hmmm… let's see what a facemask does… Oh, now I need to decide how many liters per minute to set it at… let's see what 8 does…' I had been asked all of these questions before by nurses or techs while in the hospital, so this simulation was becoming all too real.

I proceed through the history and physical exam, turning my attention occasionally to ask the nurse for more labs. As these labs start coming in, I check the results. The gears in my mind are running at full speed as I quickly draw conclusions while working on a time crunch. These results help me refine my differential diagnosis and help direct me as to what to do next.

I come to a point where I realize that I either need to decide to send her for a CT scan, or just go ahead and treat her for what I think she has (a pulmonary embolism). Accidentally, I roll my mouse over the phone on the wall, and this allows me to call several different specialties, or my attending physician for help/consultation. I decide it's probably a good idea to call my attending physician. When I do this, he tells me that the

work up I have done is adequate, and he agrees and thinks it is a pulmonary embolism as well. He recommends I get the CT scan to confirm this diagnosis. So this is what I do as the simulation comes to an end.

I'm taken through a debrief/reflection of the case during which I am prompted to think about things that went well and things that didn't go so well. After this self-reflection, I am taken to an evaluation screen where certain actions that the game expected me to do are displayed with metrics and a green/yellow/red color associated with them to indicate whether I did each action appropriately. I scroll through this feedback and look for areas where I knew that I was struggling. I do this to get clarification on how I should have been thinking and what I should have done. I find that I am deeply enjoying these games, and continue to do all of the games in rapid succession.

After completing these simulations, what Wouters (2016) has called *serious games*, my mind turns to how these serious games could be used in medical education. Particularly, I wonder how they could be incorporated best into Dell Medical School's curriculum. These serious games provide a unique opportunity for learning, and within Dell Medical School's innovative curriculum, they may find a place where their full potential could be realized. To determine where best these serious games can be incorporated, I will draw upon Pekrun's (2007) control-value theory, reflect on my own experience with serious games, and speculate regarding other students' experience with serious games using the control-value theory framework to argue for and against the placement of these serious games at various points in the curriculum. As a conclusion, I

will assert that control-value theory can be used to argue for the inclusion of serious games in the third year of Dell Medical School's curriculum. Before moving on to these issues, however, I want to define the focus of my report, *serious games*.

Definition of Serious Games

As the philosopher Wittgenstein once wrote (1953), the term *game* takes on many different meanings depending on context. When used in this paper, *serious games*, or sometimes just *games* will refer to games that have two particular features:

1) The game is on a digital platform

Many different forms of games exist such as board games, games played between people (i.e. Tag, duck-duck-goose). However, in this paper I am concerned with games that have a digital format, such as those that are used on a computer platform, or other digital device (tablet or phone).

2) The game is explicitly for educational purposes

Although a traditional game can be thought of as a recreational activity, a *serious game* is a game in which one is engaged for an educational purpose. This type of game can be incorporated into an educational curriculum and facilitates the acquisition of knowledge, skills, and strategies through participation in the game (Graesser, 2016).

Speaking broadly about digital games, these can be classified into one of three types: commercial games, game-based learning, and serious game (Connolly et al., 2012). Commercial games include much of what is thought of colloquially as video games (such

as Mario Brothers and Halo). These games are generally available to the public, are purchased for entertainment, and are not intended to have an educational component. This is not to say there is no educational value to commercial games. The initial interest in digital games as learning tools came from noting that the player of these games might derive some sort of benefit outside of the mere enjoyment of the game. Early research showed that commercial games have motivating features (Subrahmanyam & Greenfield, 1994) and might benefit the player in the development of useful skills, such as improved visual spatial abilities (Ferguson, 2007). Such findings served as a springboard for further investigations into the value of games in education (de Freitas, 2006; Gee, 2004). This led to the development of games that fall into the categories of *game-based learning* and *serious games*.

Game-based learning and serious games are designed with the intent of resulting in learning and behavior change. *Serious games* and *game-based learning* are sometimes used interchangeably (Corti, 2006), although the term *serious games* has developed a much broader definition and is more commonly used for games that take on purposes of training and behavior change within industries, businesses, as well as in marketing, healthcare, and education.

There is, not surprisingly, some lack of clarity when it comes to the categorization of digital games, such as games that can be downloaded on one's smartphone but are marketed as improving one's intelligence or keeping one sharp (i.e., a phone app that allows you to play Sudoku). Such games can be marketed from an educational

perspective, but as part of the business model of these games, the presence of advertisements and a lack of research on the app/game itself makes the categorization murky.

Current use of digital games in education has many examples: improving driving skills (Blacklunde et al., 2008), learning history (Akkerman, 2008), and acquiring surgical skills (Stefanidis et al., 2005, Nomura et al., 2008). The use of games has also been explored in adults with intellectual disabilities (Terlecki & Newcombe, 2005).

In this paper, I will not attempt to provide a clear definition for the categorization of all digital games, nor will I address how best to categorize games that fall in an ambiguous zone. I will simply acknowledge that there is ambiguity in the classification system, and that categorization may not be possible for all games. For purposes of this report, suffice it to say that there simply exists an overlap between several types of games as some educational benefit can be found in all games, regardless of the original intent of the creator. For this report, then, *serious games* are digitally delivered opportunities set up in the guise of game rules that present to a learner opportunities to acquire knowledge and skills important to the learner's educational goals.

Serious Games used in Medical Education

The utility of digital serious games in medical education has gained interest in recent years as studies have shown that these games may have positive impacts on learning outcomes. A systematic review published in 2012 by Primack et al. reported that gamified digital presentations improved clinical skills in 46% of studies, and 42% of studies showed improvement in health education outcomes. Investigating serious games in the development of surgical skills, Grantcharov et al. (2003) showed that surgeons who used these video games demonstrated better laparoscopic surgery skills than those who did not train with the video game. Rosser et al. (2007) and Schilickum et al. (2009) showed the use of games improved speed with laparoscopic surgery. This has also been shown to be the case for endoscopic/gastroscopic surgery (Enochsson et al., 2004, Stefanidis et al., 2008).

These games have been used in a broad number of medical subspecialties including internal medicine, urology, emergency medicine, neurology, anatomy, and neurosurgery (Gorbanev et al., 2003). In medical education, a blended study performed by Dankbaar (2017) demonstrated that serious games do improve student motivation for learning, although the study did not show improving performance. Medical students appear to be open to the idea of implementing serious games in medical education, with

Kim et al. (2010) showing that 77% of medical students would use these games on their own time, 80% believed that they had educational value, and 96% supported the idea that medical education should make more and better use of these new types of technologies. An advantage speculated to occur with serious games is *stealth learning* (Sharp, 2012), which is described by Wouter (2013) as "when the trainee is too busy having fun to notice an improvement on key educational outcomes." Serious games in medical education provide an exciting opportunity to improve education outcomes, while maintaining student motivation.

In this paper, I will argue for the use of Pekrun's (2007) control-value theory of achievement emotions in implementing serious games in undergraduate medical education. The use of this theory will show how best to leverage learners' emotions both during and after learning to optimize the learning process during serious game use. I will then provide my recommendations for the incorporation of serious games in undergraduate medical education, and briefly discuss how desirable difficulties and productive failure can be used to fast-track the use of serious games earlier in undergraduate medical education. I will conclude with remarks regarding the limitations of serious games.

CHAPTER 2: USING A CONTROL-VALUE THEORY LENS FOR SERIOUS GAMES

According to Pekrun's (2007) *control-value theory of achievement emotions model*, our appraisals, or judgments of our environment and of our own abilities, triggers emotional responses that relate to or can directly cause a level of engagement with the activity as well as a level of future desire for re-engagement with the activity (see Figure 1 for and overview of *control-value theory of achievement emotions*). Initial experiences with an activity in a certain setting and with certain features lead to emotions. A learner remembers these emotions, and when the learner encounters the opportunity to engage in the same activity, these emotions are used to guide future appraisals, which may lead to further engagement with the activity or with disengagement from the activity.

For example, if an activity engenders excitement, this emotion will impact future engagement and appraisals of the activity. This would be considered a positive, activating emotion within Pekrun's (2007) theory. Such positive activating emotions predict future positive engagements with the activity. Conversely, if boredom or frustration is felt, this may lead to current and future disengagement with the activity. Being negative, deactivating emotions, these would be detrimental to future approaches to the activity, causing less engagement.

Control Appraisals

In Pekrun's (2007) model, determining how emotions may be engendered with an activity is based on control and value appraisals, hence the name of the theory *control-value theory of achievement emotions*. Along the control dimension is the degree to which a learner perceives having control, that is being able to exert oneself and determine the likelihood of obtaining an outcome. This *appraisal of control* can take a prospective form, where the evaluation is made before the activity begins, or a retrospective from, where only after completion or conclusion of the activity does the evaluation for degree of perceived control occur. Within the prospective control dimension, a student is making links between a given event (cause) and a supposed future outcome (effect). Retrospectively, the student is tying effects to possible causes, the opposite of the prospective thought process engaged.

When engaging in a prospective control evaluation, the learner evaluates his/her actions with reference to two different components of the activity: ability to control one's actions while engaging in the activity (*action-control expectancies*) or whether the action will produce the desired outcome (*action-outcome expectancies*). As an example, a person who has taken up the new hobby of running would engage in action-control expectancies when evaluating her/his ability to complete a 5-mile run each day, whereas the person would engage in action-outcome expectancies when evaluating if running five miles per day will lead to the goal or outcome of becoming "more fit," however defined by that person.

With my own personal experience with the Oxford Medical Simulation, I found my initial prospective appraisal of control when I first downloaded and tried opening the software to result in negative emotions, namely frustration. The size of the download was very large, which was also acknowledged by a classmate. We shared our shock at needing to download such a large application. In reality, both of our computer storage spaces were likely more than able to accommodate such a file, but this initial exposure cast a pall on my initial perception of my ability to complete the game, and not for reasons related to having the proper medical prior knowledge to understand the cases and determine how to proceed, but merely from the process of getting the game set up to run. The frustration made me disengage from the process initially. However, I later returned to the game and actually started playing.

Applying this to medical students who are learning via serious games, their prospective appraisal of this learning situation may cause them to have positive or negative evaluations of the game. If the feeling of control the person has in getting the game downloaded and running engenders frustration, perhaps because the technology is difficult to download or confusing as to how to navigate, the student might very well have deactivating emotions as I did.

This may be particularly true if serious games were implemented earlier in the medical school curriculum. Being at the end of my fourth year of medical school, and while sheltering-in-place, I had more free time on my hands. If we had been at a different point in my medical training, I would not have had the luxury of time. Take a medical student in the first year: the medical school experience is new and unlike undergraduate

education. Information is being presented at a speed and pace the person has not seen before. Tests, deadlines, meetings, potential research papers, being with family and friends all compete for the student's limited time. When incorporating serious games into the curriculum, technological problems and issues would affect the action-control expectancies of these medical students. Care should be taken that this process is thought through, and potential areas where a loss of control in being able to complete the task could be experienced by the student should be addressed.

As for the game itself, there may be additional action-control expectancy issues. The game platform presents a unique environment that the student must learn to navigate effectively. Even with an effective orientation, the student may find it confusing or abnormal to use the game platform. As educational gaming is still a novel technology, students may experience difficulties adapting to this learning environment. This may be compounded by a navigation platform that is not intuitive to the students, both to the initial launch page of the game, as well as the interactive features/buttons within any particular game.

As a personal example, while in the game itself, I found certain navigation features/ways to perform tasks or get information to have varying degrees of ease or difficulty. When taking the history from the game patient, I found it very refreshing to see a familiar order of possible buttons to click. This question panel mirrored the order in which I have learned to do a history in the first year of medical school. This familiarity bolstered my confidence in being able to take the history from the patient and gave me confidence knowing which button to click to bring up sub-panels with more detailed

questions that could be asked. Having the game history panels organized in this manner is possible because of the standardized format that taking of a patient's history is taught to medical students. As an example, Bates Guide to Physical Examination and History Taking (see Bickley et al., 2013) presents the order of history questions taken in an order that will be familiar to nearly all medical students. There are slight differences in the details, but the overall manner of taking history is relatively constant. Having the standard reference and using this reference in the game construction added to the action-control expectancy in a positive manner for me. It is reasonable to speculate that this would be true for all students when implementing a standard approach to organizing information.

By contrast, I found the use of the medications panel to be difficult to navigate, as the way that certain drugs were categorized was not as intuitive. For instance, when looking for a statin to order for a patient, I initially went to the cardiovascular panel/button. After not finding this medication within this sub panel, I became frustrated with the navigation of this panel. (This was compounded by the slow processing speed of my computer.) Experiencing both a non-intuitive panel and a lagging computer screen did not allow me to move quickly in and out of a panel when I found I was in the wrong place. A potential fix to this medications panel could be, depending on the platform, to add a search function. Such a change would mirror real electronic health records where many medications are ordered through electronic health records, and a prompt to determine the dose is given once the medication is selected. This may sidestep the issue of having to find a particular medication within a sub panel that is not organized in a

standard way. Thus, features of game construction may lead to prospective positive or negative emotions that may impact students' decisions and desire to return to the game as a learning platform.

The other type of control appraisal within control-value theory is retrospective appraisal, where appraisals of control are made after the activity is completed. When implemented in a medical school curriculum, there may be a role for reflection with a mentor or peer to discuss how the game went. To guide these discussions, it could be valuable to have the learner distinguish between internal and external locus for success / failure (see *Cognitive Evaluation Theory* in Ryan and Deci, 2000). For example, a learner could be asked: Did the game go well / not well because of something you (the learner) did / did not do or because of something that was out of your control (software crashed)?

In these reflections, it would be important to be aware of the teaching point of each case. Beyond the routine parts that would occur in each game (wash hands, take the history, perform physical, communicate orders with nurses, check labs, etc.), each case should have a specific teaching point. For instance, one of the simulation games I played had a teaching point regarding heart failure following a heart attack. I found this game to be especially useful because the teaching point was around a pathology I did not think about during the game, and have not heard commonly discussed, but that I had learned during medical school. In fact, I made an error in the treatment of this patient. Specifically, I performed an action that should not be done in a person with heart failure, namely, giving the person a liter of fluid thinking he/she was having an inferior heart attack, and I wanted to optimize the preload (volume of blood in the heart prior to

contraction). In the debriefing section, when I saw what the learning point was and realized that my action was specifically mentioned as an error, I reflected on this disease process and determined that the locus for this error was internal. That is to say, I had learned about this disease process, was having reservations about the diagnosis that I originally used with my decision making during the simulation, and felt excited to know that I had simply forgotten some information. I was happy to find that the game was not testing me on some obscure illness. All the information was there, I simply had not connected the dots.

Although this reflection process was a positive experience for me, this may not be the case for all medical students. Depending on when in the curriculum these games are inserted, a student may not possess the necessary prior medical knowledge. At my stage of training, I had at least been exposed to heart failure following a heart attack, but first-year medical students, for instance, might not have had exposure to this material, or have had exposure but in a format that was too brief and buried within the rest of their studies that the disease process did not get incorporated into long-term memory.

In this case, the reflective appraisal might cause negative emotions in a student, and cause future lack of engagements / desire to engage with the games. The student may experience an external locus of control, such as, “I didn’t know this because we haven’t gotten to this part of the curriculum,” or “I can’t possibly remember the presentation, workup, and management of a complication of a disease we just learned last week.” Such retrospective appraisals are in line with control-value theory, as the actual causal link for the outcome might not be clearly determined, and an attribution of the outcome is made

retrospectively. Such appraisal would lead to a feeling that the student was not in control of the outcome he/she obtained, and cause negative emotions surrounding participation in the game.

Related to control appraisals in control-value theory is the self-concept of ability, which refers to a self-judgment of one's abilities in a given domain. An appraisal of one's competence in self-concept of ability is a subjective evaluation of one's skills, abilities, knowledge, or a general confidence within a particular domain. For instance, one may have the judgement of "I'm good at tennis," which foundationally frames the emotions felt by that person through playing tennis. Additionally, the self-concept of ability impacts a learner's perceived control in a given domain. This implies that if a student does not have an adequate subjective self-concept of ability, either their action-control expectancies or their action-outcome expectancies will be reduced. Both independent of and through action expectancies, a learner's self-concept of ability may induce activating or deactivating emotions.

With regards to serious games in medical education, a student's self-concept of ability should be attended to when determining when to implement these serious games in the curriculum. Medical students have largely had success throughout their education years. Medical students are high achieving, and are accustomed to being able to understand concepts and succeed in achievement situations. In medical school, however, some medical students experience a type of imposter syndrome (Willwock, 2016). A high achieving medical student is now surrounded by many high achieving students, many of whom have a list of accomplishments rivaling their own. Medical school presents

continual areas where shortcomings and struggles can be seen as failures. These struggles in medical school can have adverse mental health consequences, such as leading to depression (Rotenstein, 2016). These considerations should be kept in mind when implementing serious games.

Let us consider, for example, serious games implemented early in medical school during the preclinical curriculum. There will be variability, similar to reflective appraisals discussed earlier, in how students evaluate the negative aspects of their performance. It is likely that at least some students will have deactivating emotions that impact their self-concept of ability. Through struggles with the serious games, comparisons to peers, possible struggles in other courses, and life circumstances, a medical student may develop any number of lowered self-concepts of ability related to topics presented in serious games. For instance, a medical student may appraise themselves as, "I'm not good at interpreting lab results," or "I'm not good at reading chest x-rays," or "I'm not good at developing a differential diagnosis," all of which are necessary and present to some degree in serious games in medical education.

Control appraisals in control-value theory are important mediators for emotions and future engagement. These control appraisals occur frequently, both prospectively and retroactively, and with regards to both actions and outcomes. In deciding whether and when to use serious games in undergraduate medical education, medical educators should consider the impact of control appraisals in making decisions regarding when and how to use serious games.

Value Appraisals

The second category of appraisals made by a learner in control-value theory are value appraisals. According to the theory, a learner engaged in an activity makes value judgements that are directed towards both the activity and the outcome. These value appraisals of an activity can be intrinsic or extrinsic, and either positive or negative. Take the activity of running. An avid runner may find intrinsic value in the act of running, hence having a positive value judgement for the act of running, enjoying the act in-and-of-itself, without reference to some outside result or outcome. It could also be the case that a runner enjoys running not only intrinsically, but also for the instrumental function of the activity, such as improved health or social status from running abilities. Whether with reference to an activity or outcome, or if internally or extrinsically valued, the appraisal can be positive (and thus beneficial) or negative (and thus detrimental).

Reflecting on my personal experience with serious games, the value judgement I made was initially positive with respect to both the intrinsic and extrinsic nature of the activity and outcome, but later I realized I placed less of an intrinsic value on the games. On my initial play through, I enjoyed playing the game for itself. The simulation provided by the game took me back to the hospital and was a welcome reprieve from my shelter-in-place status. This can be seen as having intrinsic value related to the activity itself. However, as I played more games, I began to develop a negative intrinsic value of the activity of playing the game. The novelty of playing the game wore off, and soon, taking the history and physical and entering orders became more tedious and monotonous than a new, enjoyable experience. I found myself getting frustrated as I had to wait a

minute for lab results to arrive, with little to do in the interim. I still maintained extrinsic value for the outcome, that is the teaching point of the game was still useful to me, but many of the actions required to get there were less enjoyable. I did, however, place positive value appraisals on the second half of the games when I had to interpret labs and x-rays or had to make decisions related to what treatment course to start with the patient, especially when there was a degree of ambiguity in what the "best" treatment was and I was left to decide between several medications.

I also intrinsically valued the outcome of the activity. As described previously, the game had teaching points from which I was able to learn by playing the games. This outcome of having learned something provided an additional extrinsic value as it aligned with my goals and identity-related needs. I also valued the game because it provided course credit for my last requirement of medical school, thus instilling the act of playing the game with an extrinsic value related to outcome.

In considering the positive and negative effects serious games could have when used in medical education, the student's value appraisals may provide a guide to determining when to implement serious games in the curriculum. Consider a 4th year student who is about to graduate medical school and start a plastic surgery residency. This student is assigned a serious game as part of a clerkship, but the design of the game has the teaching points more focused on medical conditions, and does not incorporate surgical problems and diagnoses to the same extent. Within control-value theory, this student may develop a net negative value judgement, and negative emotions for the game. It could still be the case that the student would intrinsically value the action of

playing the game (as there is novelty to this learning platform). However, the student may soon develop an overall negative value judgement of both the action and outcome. The largest factor in this appraisal could be the judgment of the extrinsic outcome. Depending on the specialty the student has chosen, the topics of the cases may not present a value to learn / review / play. For me, playing a game where heart failure following a heart attack was appraised positively. A student going into plastic surgery may not have this same value appraisal.

Control-value theory provides a unique lens for evaluating the best use of serious games in undergraduate medical education. Advantages and limitations are present when considering using serious games at any point of a medical student's education. Control and value appraisals of the serious games will be made continually by students, which will impact future desire to engage in serious games. By considering where medical student are in their education, and the structure of the curriculum, a more definitive decision can be reached for the use of serious games. This is what I turn to in the next chapter.

CHAPTER 3: RECOMMENDATIONS FOR USING SERIOUS GAMES IN MEDICAL EDUCATION

In this chapter, I advance some recommendations for how serious games could be implemented to the benefit of medical students' learning and motivation. In order to situate my recommendations appropriately, I begin by describing one particular medical school and its organization. I then move to a consideration of recommendations for the use of serious games for medical education using control-value theory as a basis for these recommendations.

Organization of the Curriculum of Dell Medical School, University of Texas at Austin

Undergraduate medical education provides a unique opportunity for the implementation of serious games but this implementation must be appropriate to the particular context in which it occurs. There is a wide diversity of curricula in medical education, with different medical schools having quite different approaches to teaching medicine to their students. As such, making generalized recommendations for serious games can be difficult. To circumvent this, I will present recommendations for the

incorporation of serious games into one specific medical school, Dell Medical School at the University of Texas at Austin.

Dell Medical School has an innovative curriculum, referred to as the Leading EDGE Curriculum. In this curriculum, the first-year of medical school presents learners with the Essential basic science information foundational to being a physician. In the second-year, students apply their clinical skills through Delivery of healthcare to patients in hospitals and clinics in the Austin area. A Growth stage is entered during the third-year of medical school, allowing students to gain experience in an area of personal interest which may include obtaining a dual-degree such as a Masters in Business Administration or a Masters of Education. Finally, in year-four, students engage in an Exploration phase where a deeper dive into their desired specialty occurs, and additional healthcare electives, rotations, and a final capstone transition-to-residency serves to prepare students for success in their careers. This Leading EDGE (Essentials, Delivery, Growth, and Exploration) is an innovative rethinking of medical education, presenting a unique opportunity for the use of serious games to enhance the learning experience of its students.

In order to attempt to make students' well-being, their motivation to learn, and especially their emotions positive and engaging, I am arguing that it is important to consider the likely control and value appraisals a learner will make both during and after participation in these serious games, to which I turn in the next sections.

Recommendations about Control and Value Appraisals

Recommendations for the use of serious games in Dell Medical School's curriculum take two forms: timing of implementation in the curriculum and topic of serious game. These will be interwoven into the recommendations. Using serious games early, such as in the first year of medical school, may result in negative appraisals of control, both with regard to the activity and the outcome. First-year students are likely not to have the adequate prior knowledge nor to have had clinical exposure to understand the options available in the game (such as calling consults, or even what fluids are best to give to which patients), and thus could have negative deactivating emotions as their appraisal of control of the action would be negative.

Conversely, using serious games too late in medical education may result in negative value appraisals as students who have already been accepted into a specific residency might not find value in the particular learning points of a specific game if not directly related to their specific field of study. As I mentioned earlier as an example, a student going into plastic surgery may not find value in a serious game related to medicine topics (i.e., presentation and treatment of a heart attack). However, medical students further in their education might benefit more from specialty-specific serious games. Doing so might engender excitement and stimulate deeper learning from the serious game as it is more directly related to the specialty the student is pursuing. For example, a student who is going into urology would benefit more from playing a urology specific serious game than they would playing a medicine related serious game. An

obvious limitation of this approach would be the cost to have such serious games available, but the potential upsides might counterbalance this potential issue.

When considering how to incorporate serious games into a medical school curriculum, value judgements identified in Pekrun's (2007) control-value theory made by students may provide guidance as to where to place the games in the curriculum. Earlier in medical school, students are more exploratory with regards to their consideration of going into different fields. Many students have not yet decided what specific field they want to choose as their medical career and are more open to experiences in various fields. Additionally, students are still taking board exams early in medical school, which require knowledge in a broad range of fields. Viewed with this in mind, control-value theory can be interpreted as predicting positive value judgements on the part of medical students if the serious games are incorporated earlier in medical school. This may also be compounded by the fact that medical students often do not have direct exposure to patients in the early part of their medical education. Providing students with the opportunity to interact with a simulation of a patient encounter could be of value earlier in their medical education. A potential drawback to this opportunity is the lack of prior knowledge, as has been discussed. As such, the implementation of these games should be considered within the context of the curriculum as a whole.

Mapping these considerations onto the Dell Medical School curriculum, control value theory can be used to argue that these serious games might be most effective if implemented in the latter part of the third year of the curriculum. During this third year, students are largely taken away from clinical settings as they engage in another degree

awarding or certificate awarding distinction tracks. As they approach the end of their third year, and begin to face the beginning of their fourth year, they may benefit from refreshing their medical knowledge before returning to clinical duties. These third-year students have been exposed to the information necessary to be successful in the serious games (and thus, they would have control both over their actions and outcomes in the game) and would still need to know the teaching points and information taught in these games to go through fourth year rotations (thus seeing the value of the game).

At Dell Medical School, the second year contains the core clinical rotations for medical students. Here, medical students rotate through internal medicine, surgery, emergency medicine, and other core specialties. Students spend much of their time interacting with patients and engaging in activities essential to being a physician, and are in the real-life version of what serious games attempt to represent. As such, serious games may have less utility in the second year of medical school. In a study conducted by Kim et al. (2018), students were given serious games while on either pediatrics, family medicine, or internal medicine clerkships. In their analysis, they obtained qualitative data from students involved in the study. Two comments from students provide insight regarding the use of serious games during clinical rotations which can be related back to control-value theory. The first student stated, "*We are getting this on the floors, and we are investing our time in doing that. To go home and redo another version of that? Like why are we doing another version of that? It is more beneficial to study and direct our own learning."* Interpreting this quote through a control-value theory lens, it can be speculated that this student is making a value appraisal of serious games, expressing that

the serious games do not aid in obtaining the outcomes important to the student, such as studying for board exams or reading on patients seen during clinical duties. Participating in these serious games while on clinical rotations may have engendered frustration on the part of the student which impacts his or her future thoughts regarding serious games. A second student stated, "*These would be great resources in the second year, preparing to go out on the floors."* With this student, it is assumed that the medical school from this study has a traditional curriculum with two pre-clinical years and two clinical years. Again, through a control-value theory lens this quote can be interpreted as the student expressing a lack of perceived value with regards to obtained from playing serious games while on clinical rotations. In sum, using control-value theory indicates serious games may not have a utility in the second year of Dell Medical School's curriculum. As such, it is recommended that serious games not be used during Dell Medical School's second year, or during core clinical rotations at other medical schools.

Another consideration should be given to the potential frustrations or other negative deactivating emotions engendered when first using these serious games. Being a novel technology, students may lack familiarity with gaming platforms. Despite the pervasive nature of these gaming technologies in society, it is likely that students have played video games, of a non-educational type before. These prior experiences may aid students in their experience with serious games. However, given the desire from an educational perspective to leverage the full potential of serious games, an effort to mitigate potential negative deactivating emotions when initially interacting with the platform should be attempted. Gee (2003) discusses the utility of walkthroughs, manuals,

and instruction booklets in serious games. These attempts to orient learners to the platform are received with mixed results. Often, players overlook these resources and opt to start playing the game directly, as I did. He argues that video games are so good at teaching players how to play them, that these orientation materials may not provide an additional benefit. Applying this to serious games in medical education, it should not be expected that students will want to engage in a separate tutorial or read any materials given to explain how the game works. A game that considers how to embed this into the natural playing of the game will suffice.

Serious games provide a unique learning opportunity for medical students. Using a control-value theory lens, it is speculated that serious games might be most beneficial when used during the first year of medical school or towards the end of the third year of medical school, if general medicine serious games, or towards the end of medical school if specialty specific serious games.

CHAPTER 4: CONCLUSION

So far, we have discussed the utility of control-value theory for serious games in medical education. Control appraisals and value appraisals by learners both during and after participation in serious games will engender emotions which will affect future engagement with serious games. Attending to these emotions through course timing of implementation may cause positive engaging emotions to be experienced by the learner. While a valuable lens, there are other theories from educational psychology that may be useful in guiding choices about the use of serious games. One such theory, which desires mention in the context of medical education, is the idea of desirable difficulties. We will now turn to this theory and see how it guides our understanding of serious games in medical education.

Desirable Difficulties and Productive Failure when using Serious Games

Serious games present a unique learning opportunity in medical education. However, the desire to introduce this exciting new form of learning early in undergraduate medical education produces some difficulties. First, a medical student in her/his first year has limited knowledge and thus may experience failure while playing a serious game. One way to overcome this is to construct a serious game that plays at the

medical student's current knowledge level. Constructing such a game would require coordination amongst various fields and with game developers.

Alternatively, a second option would be to use these serious games despite them not being at a first-year medical student's level of knowledge, with the intention of inducing productive failure. The Oxford Medical Simulations I used would be such an example. In using these, students would need to be informed that these serious games are above their knowledge level but that they will learn and succeed if they keep trying. Using the frame of desirable difficulty, there might be a solution to this issue.

As outlined by Kapur (2016), there are four possibilities for designing a successful intervention in education. First is productive success. An example of this would be a problem-based learning and guided inquiry where scaffolding and problem-solving activities allow for a learner to gain expertise. The second is productive failure. With productive failure, "students will not typically be able to generate or discover the correct solution(s) by themselves. However, to the extent that students are able to use their prior knowledge to generate suboptimal or even incorrect solutions to the problem, the process can be productive in preparing them to learn better from the subsequent instruction that follows" (Kapur, 2016, p. 289). Third is unproductive success. This is what is typically viewed as memorization of information without application to a tangible problem. Finally, there is unproductive failure which is pure discovery learning where a student does not have guidance or support whatsoever, and the floundering that takes place teaches the student very little.

The second option, productive failure, provides a unique opportunity within medical education. Productive failure could be used as the framework to introduce serious games to first-year medical students. It should be disclosed upfront to the students that they will encounter issues / problems within the game for which they have yet to acquire the appropriate knowledge (i.e., determining the best fluids to give a patient who is in diabetic ketoacidosis).

In order to ensure that first-year medical students are not falling into unproductive failure, I propose that a first-year medical student be paired with a third- or fourth-year medical student to play these serious games. Having the additional knowledge, these medical students would provide guidance to the first-year medical student when playing serious games. This also provides a benefit to the senior medical students as they are soon to transition into residency, and are expected to educate their peers as well as medical students who are assigned to their service. Within this plan, it would likely be necessary to have a training session for these upper-level medical students so they are most effective in their teaching / guidance of first-years through these games. Such sessions might use scaffolding (see Wood, Bruner, & Ross, 1976) as a theoretic framework to orient the upper-level medical students in their approach to sessions. Framing serious games within such confines might result in success earlier in medical school for serious games.

These serious games provide a safe opportunity outside of a hospital for a medical student who is early in training to experience the process of taking history and developing

a differential diagnosis and plan on a simulated patient who has a serious issue. Having the third- or fourth-year medical student to guide a first-year student through this process would guard against unproductive failure, while at the same time giving the senior medical students opportunities to develop their teaching abilities. This also may address a limitation presented by Haoran et al. (2019) who reviewed serious games in medical education and concluded that they are best for short-term learning. Based on research done by Bjork (1994), introducing difficulties during learning can actually increase long-term retention and transfer. Attempting to model this with serious games during the first year of medical school may actually address this limitation of serious games.

Limitations of Serious Games

While an exciting tool that could be used in medical education, serious games are not without their limitations. Most importantly among these are difficulties with study design, and the current lack of efficacy of serious games for education outcomes demonstrated by studies already conducted.

The evidence for these *serious games* has been called into question. Gorbanev et al. (2018), Graafland et al. (2012), Akl et al. (2010), and Abdulmajed et al. (2015) have all investigated the quality of the evidence for serious games in medical education. Graafland et al (2012), reviewing medical education games published from 1995 to 2012, found “games developers paid little attention to game effectiveness validation.” Akl et al. (2010) reviewed articles published prior to 2007, finding no evidence in favor of, nor

against the utility of educational games as teaching strategies. Abdulmajed et al. (2015) reviewed five games published between 2002 and 2010, and did not have a definitive conclusion regarding game effectiveness, although the method to assess the games was not explicit. Gorbanev et al. (2018) reviewed 21 serious game articles and assessed them using Kirkpatrick's criteria (see Kirkpatrick, 1967), commonly used in medical education for the evaluation of studies and their results for training and education programs. Level one is *reaction*, which would be a study that measures study participant's satisfaction with an intervention. Level two is *learning*, where a study shows acquisition of knowledge, skills, attitude, or some other metric which is deemed to have been "learned." Level three is *behavior,* where a study is able to show changes in behavior, or to apply what was learned in the real world. Level 4, the highest level, is a study that is able to show the impact of the intervention on the actual end-target. In medicine, this would be showing that learning on the part of the learner results in better patient outcomes (Abdulghani et al., 2014). Gorbanev et al. (2018) in their review concluded that these games only reached level 2 on Kirkpatrick's criteria. Further research attempting to demonstrate change in behavior in the clinical setting, or, best of all, improved clinical outcomes, would bolster the evidence base for serious games.

Continuing the concern with the evidence for serious games in medical education, Drummond et al. (2017) argued for randomized control trials to be utilized more regularly. Less than 20% of the studies done regarding serious games in medical education have used this gold standard design (Primack et al. 2012), making the analysis

of the data from serious game studies relative to traditional forms of teaching difficult if not impossible to interpret. Specifically, Drummond et al. (2017) called for randomized control trials to have three groups: an intervention group with serious games, a control group with traditional forms of teaching, and another control group with no education on the topic whatsoever. This third group is reported as being needed because "The use of a control group who receives no education is essential to demonstrate the effectiveness of a serious game and still remains ethical because it happened that an intervention group playing a serious game failed to reach higher levels of knowledge and/or skills than a control group receiving no education" (Huss et al. 2003). In determining what the *traditional* learning mode would look like, the authors also stated serious games should be compared to "long and expensive training in simulation centres," but it is reasonable also to compare them to less expensive and widely used methods of training, such as lecture-based teaching and problem-based learning. In measuring the utility of serious games, Huss et al. (2003) also advocated for the use of the Kirkpatrick model, and stated the first level of "satisfaction" should be avoided because "there is no evidence satisfaction alone leads to effective learning." They recommended constructing a study that answers to the second level, which includes acquisition of skill and knowledge as assessed through the use of questionnaires and physical simulations.

As these serious games are utilized in the context of a medical school curriculum, it is difficult to determine which learning outcomes can be attributed to the serious game as opposed to the curriculum itself. This is complicated by the fact that running

randomized controlled trials has been limited. As such, the instructional design/research design of studies should incorporate more robust ways to show a connection between the serious game in the outcome measure.

Conclusion

Serious games provide an exciting new opportunity for education of students during their medical school careers. Control-value theory of achievement emotions provides a useful backdrop for serious games when considering how best to incorporate them into medical school curriculums. Within this theory, consideration should be given as to how students will perceive their ability to control performance in playing the game, and how much control they have over the outcome, as well as how a student might perceive value in the use of serious games. As such, implementation of serious games might be best earlier in the medical school curriculum, if a game with broad learning points is used, or if used with the desire to induce desirable difficulties and productive failure. Alternatively, these games can be used later in undergraduate medical school education, but with more specific content that is tailored to the students' specialties.

FIGURES:

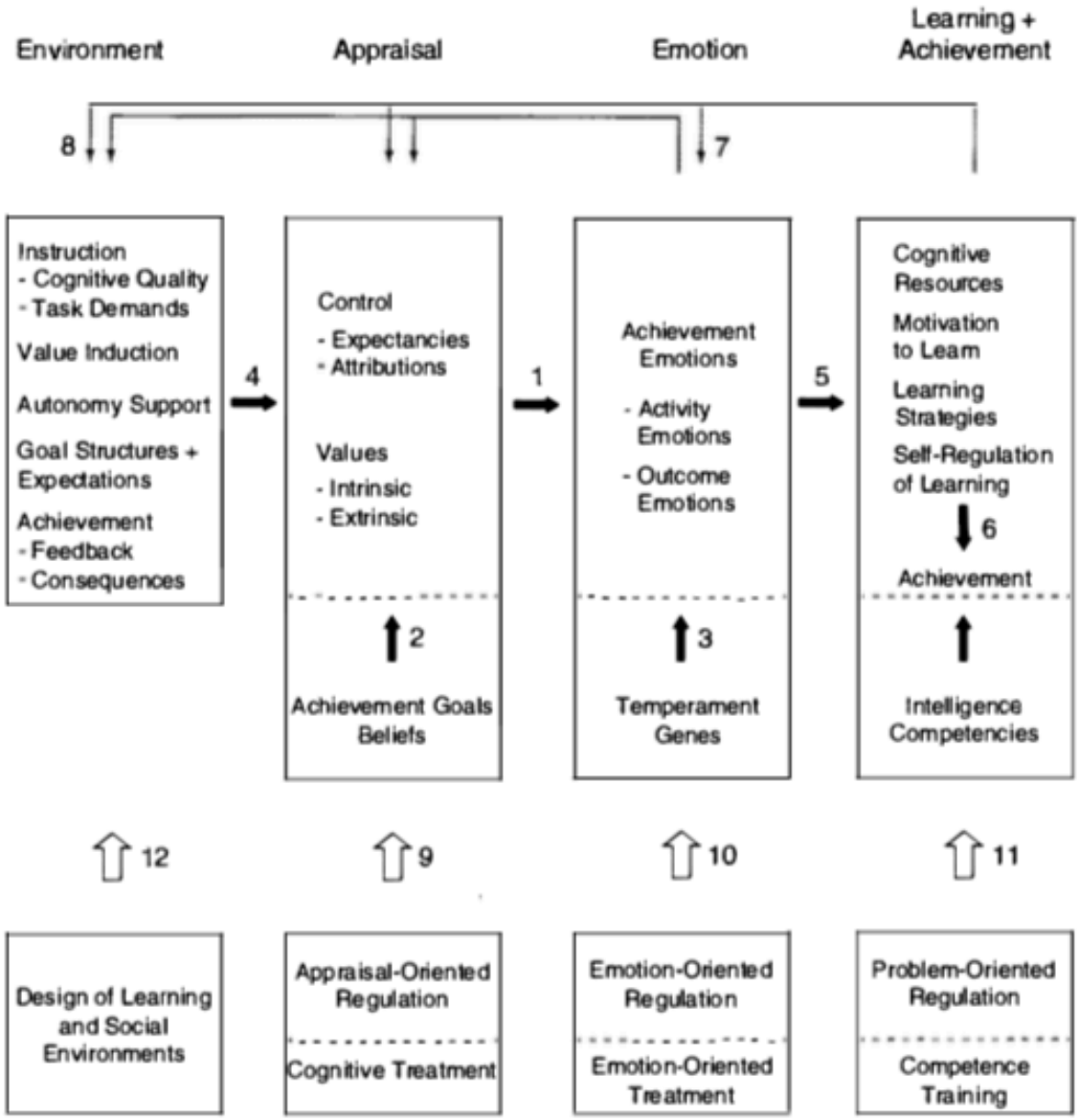

Figure 1: Overview of Control-Value Theory from Pekrun et al., 2007

REFERENCES:

Akl E, Pretorius R, Sackett K, et al. The effect of educational games on medical students' learning out- comes: a systematic review: BEME Guide No 14. J Med Teacher. 2010;32(1):16–27.

Abdulghani, H.M., Shaik, S.A., Khamis, N., Al-Drees, A.A., Irshad, M., Khalil, M.S., Alhagwi, A.L. & Isnani, A. (2014). Research methodology workshops evaluation using the Kirkpatrick's model: Translating theory into practice. *Medical Teacher*, *36*(Suppl.), S24–S29.

Abdulmajed H, Park Y, Tekian A. Assessment of educational games for health professions: a systematic review of trends and outcomes. Med Teach. 2015;37 (Supplement):S27–S32.

Bjork, R. A. (1994a). Memory and metamemory considerations in the training of human beings. In J. Metcalfe & A. Shimamura (Eds.), Metacognition: Knowing about knowing (pp. 185–205). Cambridge, MA: MIT Press.

Bickley, L., Szilagyi, P. and Bates, B., 2013. Bates' Guide to Physical Examinaiton and History Taking. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686.

Dankbaar, M. (2017). Serious games and blended learning; effects on performance and motivation in medical education. *Perspectives on Medical Education*, *6*(1), 58–60.

Drummond, D., Hadchouel, A., & Tesnière, A. (2017). Serious games for health: three steps forwards. *Advances in Simulation*, *2*(1). https://doi.org/10.1186/s41077-017-0036-3

Enochsson, L., et al.: Visuospatial skills and computer game experience influence the performance of virtual endoscopy. J. Gastrointest. Surg. **8**(7), 876–882 (2004). Discussion 882

Ferguson, C. J. (2007). The good, the bad and the ugly: A meta-analytic review of positive and negative effects of violent video games. *The Psychiatric Quarterly*, *78*(4), 309–316.

Gee, J. P. (2004). *What video games have to teach us about learning and literacy* (1. paperback ed). Palgrave Macmillan.

Graafland M, Schraagen J, Schijven M. Systematic review of serious games for medical education and surgical skills training. Br J Surg. 2012;99(10):1322– 1330.

Graesser A.C. (2017) Reflections on Serious Games. In: Wouters P., van Oostendorp H. (eds) Instructional Techniques to Facilitate Learning and Motivation of Serious Games. Advances in Game-Based Learning. Springer, Cham

Grantcharov, T.P., et al.: Impact of hand dominance, gender, and experience with computer games on performance in virtual reality laparoscopy. Surg. Endosc. **17**(7), 1082–1085 (2003)

Haoran, G., Bazakidi, E., & Zary, N. (2019). Serious Games in Health Professions Education: Review of Trends and Learning Efficacy. *Yearbook of Medical Informatics*, *28*(1), 240–248.

Huss K, Winkelstein M, Nanda J, Naumann PL, Sloand ED, Huss RW. Computer game for inner-city children does not improve asthma outcomes. J Pediatr Health Care. 2003;17:72–8.

Kapur, M. (2016). Examining Productive Failure, Productive Success, Unproductive Failure, and Unproductive Success in Learning. *Educational Psychologist*, *51*(2), 289–299.

Kim, S., Willett, L. R., Pan, W. J., Afran, J., Walker, J. A., & Shea, J. A. (2018). Impact of Required Versus Self-Directed Use of Virtual Patient Cases on Clerkship Performance: A Mixed-Methods Study. *Academic Medicine*, *93*(5), 742–749.

Kirkpatrick, D.L. (1967). Evaluation of training. In Craig, R.L. & Bittel, L.R. (Eds.), *Training and development handbook* (pp. 87–112). New York, NY: McGraw Hill.

Primack BA, Carroll MV, McNamara M, Klem ML, King B, Rich M, et al. Role of video games in improving health-related outcomes: a systematic review. Am J Prev Med. 2012;42:630–8.

Pekrun, R., Frenzel, A. C., Götz, T., & Perry, R. P. (2007). *The control-value theory of achievement emotions: An integrative approach to emotions in education*. 24.

Rosser Jr, J.C., et al.: The impact of video games on training surgeons in the 21st century. Arch. Surg. **142**(2), 181–186 (2007).

Rotenstein, L. S., Ramos, M. A., Torre, M., Segal, J. B., Peluso, M. J., Guille, C., Sen, S., & Mata, D. A. (2016). Prevalence of Depression, Depressive Symptoms, and Suicidal Ideation Among Medical Students. *JAMA*, *316*(21), 2214–2236.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology*, *25*(1), 54–67.

Schlickum, M.K., et al.: Systematic video game training in surgical novices improves performance in virtual reality endoscopic surgical simulators: a prospective randomized study. World J. Surg. **33**(11), 2360–2367 (2009)

Sharp L A. Stealth learning: Unexpected learning opportunities through games. Journal of Instructional Research. 2012;1:42–8.

Shute, V., Ventura, M., Bauer, M., and Zapata-Rivera, D., "Melding the power of serious games and embedded assessment to monitor and foster learning: flow and grow," in *Serious Games: Mechanisms and Effects*, U. Ritterfeld, M. Cody, and P. Vorderer, Eds., pp. 295–321, Routledge, Taylor and Francis, Mahwah, NJ, USA, 2009.

Stefanidis, D., Acker, C., Heniford, B.T.: Proficiency-based laparoscopic simulator training leads to improved operating room skill that is resistant to decay. Surg Innov **15**(1), 69–73 (2008)

Villwock, J. A., Sobin, L. B., Koester, L. A., & Harris, T. M. (2016). Impostor syndrome and burnout among American medical students: A pilot study. *International Journal of Medical Education*, *7*, 364–369.

Wittgenstein, Ludwig. 1953. *Philosophical Investigations*. Oxford: Basil Blackwell. Translated by G. E. M. Anscombe.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *17*, 89–100.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology*, *105*(2), 249–265.